A4 and insert --of the etching chamber in a range--~~, same line~~

~~10, after "120 °C" insert --,--;~~

Line 11, delete "the";

Line 12, delete "the" and insert --a--, same line 12, after "and" insert --a--;

Line 14, after "and" insert --,--;

Line 15, after "also" insert --,--, same line 15, delete "a" and insert --the--;

Line 16, delete "an" and insert --a simplified--;

Line 17, delete "performed" and insert --obtained--.

REMARKS

The specification and abstract of the disclosure have been amended to correct errors of a typographical and grammatical nature. Due to the excessive corrections thereto, applicants submit herewith a Substitute Specification, along with a marked-copy of the original specification for the Examiner's convenience. Applicants submit that the substitute specification includes no new matter. Therefore, entry of the Substitution Specification is respectfully requested.

The claims have also been amended to more clearly describe the features of the present invention.

Entry of the preliminary amendments and examination of the application is respectfully requested.

To the extent necessary, Applicants petition for an extension of time under 37 CFR § 1.136. Please charge any shortage in fees due in connection with the filing of this paper, including extension of time fees, to the Deposit Account No.

01-2135 (Case No. 503.37698X00) and please credit any excess fees to such Deposit Account.

Respectfully submitted,

ANTONELLI, TERRY, STOUT & KRAUS, LLP

William I. Solomon

William I. Solomon
Registration No. 28,565

1300 North Seventeenth Street
Suite 1800
Arlington, VA 22209
Tel.: 703-312-6600
Fax.: 703-312-6666

WIS/DRA/slk

Title of the Invention:

A PLASMA PROCESSING APPARATUS AND A PLASMA PROCESSING METHOD

Background of the Invention:

The present invention relates to a plasma processing
apparatus and a plasma processing method, and, in
particular, the invention relates
particularly, to an apparatus for etching an insulation
film, such as a silicon oxide film of a wafer, using a
. The invention
plasma and relates to a plasma etching apparatus and a
plasma etching method having a plasma generation source
is capable of effecting   processing
which can be corresponded to a minute practicing of an
is   able to maintain
etching pattern, and further enable for maintaining a
of operation
stable etching characteristic during a long period.

One example of a   is
Among conventional plasma processing apparatuses, an
oxide film plasma etching apparatus is exemplified, and the
used thereby the inherent in known
techniques and problems of this apparatus are shown. As
a   for use in
the conventional plasma source of an oxide film use plasma
etching apparatus, a type which is used most widely is a
narrow electrode type high frequency plasma generation
apparatus, which is comprised of a pair of opposing opposed
electrodes.

Of the known   of
The systems of the narrow electrode type high
frequency plasma generation apparatus have known that,
there is a system in which a high frequency having from
13.56 MHZ to a several 10 MHZ degree is applied to one
electrode and to another electrode by mounting a wafer a

high frequency bias ~~having~~ of about 1 MHZ ~~to the wafer~~ is applied separately to the other electrode on which a wafer is mounted, and there is another system in which a high frequency is applied to ~~a~~ the pair of electrodes.

In this narrow electrode type of plasma source ~~system~~ etching apparatus, since ~~a~~ the distance between the electrodes is narrow, (for example, from 20 mm to 30 mm, it is ~~called~~ known as a narrow electrode type plasma source and a parallel flat plate type plasma source.

Further, in the narrow electrode type plasma source, it is difficult to generate a plasma ~~generation at~~ in a region where ~~a~~ the pressure is low, however, by ~~an~~ the addition of ~~a function of~~ a magnetic field ~~application etc.~~, an apparatus is obtained in which a lowering of ~~a~~ the discharge pressure ~~is~~ can be achieved ~~improved is used~~.

~~Further, in~~ In addition to the above-stated narrow electrode type of apparatus, other plasma etching apparatuses have been known~~, these~~. These apparatuses ~~are one~~ include a plasma etching apparatus having an induction type plasma source in which an induction coil is used and another plasma etching apparatus ~~having~~ in which a ~~microwave~~ plasma etching microwave is introduced.

In these apparatuses having an induction type etching source and ~~the~~ a microwave type plasma source ~~sources~~, it is possible to generate and maintain the plasma under a low pressure, and ~~further~~, since ~~a~~ the plasma density is high, ~~the above-stated~~ such a plasma source is ~~called~~ known as a low pressure and a high density plasma source.

In ~~a~~ silicon oxide film etching, as an etching gas,

~~one~~ a mixture gas, in which ~~to~~ argon (Ar), a gas including carbon (C) and fluorine (F), such as C_4F_8, and a gas including hydrogen (H), such as CHF_3, are mixed, is used, and, further, another mixture gas, in which oxygen (O_2) and ~~a~~ carbon monoxide (CO), and hydrogen (H_2) etc. are added to the above-stated ~~one~~ mixture gas, is used.

These gases are dissociated by the plasma and are dissolved to form CF_3, CF_2, CF, and F. ~~An~~ The amount and ~~a~~ the ratio of this gas molecule species ~~gives largely an~~ exerts a large influence on ~~an~~ the etching characteristic of the silicon oxide film (hereinafter, it ~~is called~~ will be referred to merely as an "oxide film").

In ~~particularly~~ particular, in the case of ~~the~~ a high density plasma source, since ~~an~~ the electron temperature in the plasma is high, ~~the~~ plasma dissociation progresses ~~is progressed~~, and the plasma ~~has~~ comes to have many fluorine gas ~~molecule kind~~ molecules F. Further, ~~an~~ as the ionization progresses, ~~is progressed and~~ it has a ~~feature in which~~ ~~a~~ the ratio of ~~a~~ ~~neuter~~ neutral gas molecule species (radicals) ~~is~~ becomes low.

~~With~~ For these reasons, in ~~the~~ oxide film etching ~~according to the~~ with a high electron temperature and ~~the~~ a high density plasma, since ~~an~~ the amount of CFx (CF_3, CF_2, CF) which adheres to a silicon surface, which is ~~being~~ a foundation of the oxide film, is lowered, there are problems in ~~which an~~ that the etching speed of the silicon (Si) is large and ~~a~~ the selection ratio is small.

As means for solving the above stated problems, a method for increasing the CFx radical amount in the plasma

has been known, ~~namely a~~ in which the temperature of ~~a~~ the wall face of ~~an~~ the etching chamber is ~~risen~~ raised to about 200 °C, ~~and a~~ in an effort to discharge the deposition film which ~~is~~ has adhered to the wall face ~~is tried to discharge, and an~~ by reducing the adhesion ~~to~~ of the deposition film to the wall face of the etching chamber ~~is restrained~~.

As a result, in ~~the~~ an apparatus in which ~~the~~ a high density plasma is used, to obtain the desired selection ratio, a high temperature performance of the wall face of the etching chamber becomes indispensable.

An oxide film etching apparatus described in Japanese application patent laid-open publication No. Hei 7-183283 is an example of an apparatus in which ~~where~~ a wall face of an etching chamber is formed to have a ~~with the~~ high temperature performance.

As a countermeasure for obtaining the high selection ratio in addition to the above technique, there is a ~~it has~~ known ~~a~~ method in which ~~an~~ the electron temperature in the plasma is lowered and ~~a~~ plasma dissociation is restrained. ~~In~~ More specifically ~~concretely~~, in this method the ~~a~~ plasma application is carried out intermittently, and so this method is called ~~as~~ a pulse plasma method.

As another one example ~~for~~ of obtaining ~~the~~ a high selection ratio, there is a method in which materials for consuming ~~the~~ fluorine (F) are installed in an etching chamber in advance. In Japanese application patent laid-open publication No. Hei 9-283494, ~~the above stated~~ such a method is described ~~shown~~, in which a side wall of an etching chamber is

constituted by silicon (Si), and a heating means ~~of~~ for heating the side wall and a bias application means are provided, ~~and~~ so that the fluorine (F) in the plasma is consumed.

In ~~the~~ oxide film etching in which ~~the~~ narrow electrode type of plasma generation is used, in correspondence with the fine ~~practicing~~ patterning in which a device pattern size ~~moves to~~ is less than 0.25 μm, ~~to a portion to be subjected the etching~~ it is necessary to make the ~~extremely small a~~ scattering of the ~~an~~ ion incident angle at a portion to be subjected to the etching extremely small.

Since the scattering of the ion incident angle causes an abnormality of ~~an~~ the etching shape and ~~an ion amount for~~ a decrease in the number of ions reaching ~~to a~~ the bottom of a deep hole ~~is decreased~~, ~~there are~~ problems are caused including ~~in which~~ a lowering of ~~an~~ the etching speed ~~is caused~~ and a ~~stop~~ premature stopping of the etching ~~is caused~~ in the formation of holes.

~~The~~ This scattering of the ion incident angle is caused by ~~the cause in which~~ ~~an~~ the incident angle distribution ~~has~~ having a spread angle because the ions collide with ~~the~~ radicals in the plasma.

To solve the above stated problems, it is effective to decrease the number of collisions between ions and ~~collision of the ion with the~~ radicals~~,~~ ~~in concretely~~; more particularly, it is necessary to lower the pressure.

As a result, in the narrow electrode type of plasma generation apparatus ~~in which~~, because it is difficult to carry out the plasma discharge ~~is~~ ~~difficult to carry out~~ under ~~the~~ low pressure conditions, even under ~~the~~ a low pressure sufficient to ~~enable for~~ generate ~~the~~ a plasma, ~~there~~ it is ~~devised~~ proposed that the frequency of the plasma generation

source ~~is~~ be made ~~to the~~ high ~~frequency~~ and ~~the~~ that a magnetic field ~~is~~ be applied.

Further, in the narrow electrode type of plasma source in which the distance between the electrodes is narrow, in a case where ~~the~~ a low pressure ~~pressurization~~ is used ~~devised~~, since ~~an~~ the average free path distance ~~stroke~~ of the gas molecules ~~molecule~~ becomes long, the collision frequency of the gas molecules ~~together with~~ is decreased, and, in place of this, the collision between the gas molecules and the electrode becomes dominant ~~dominate~~.

This is not a preferable condition, since, in ~~as~~ the etching apparatus, ~~in which~~ according to the collision of the gas molecules in the plasma, it is necessary to control the maintenance and the reaction of the plasma~~,~~; and, as a result, in order ~~so as~~ to accomodate a ~~correspond the~~ low pressurization, it is necessary to provide a ~~form~~ large ~~the~~ electrode interval.

When the electrode interval is ~~formed~~ wide, ~~a rate~~ the surface ~~of an~~ area of the side wall ~~which~~ occupied with a ~~surface area~~ in the etching chamber becomes large. Here, the ~~The~~ surface of the etching chamber is the surface ~~indicates one~~ which is subjected to the plasma, and the surface does not include a surface of ~~a~~ the top plate (~~a~~ ceiling), a surface of ~~a~~ the floor, and a surface of the electrode (the wafer).

Until now, in the narrow electrode type plasma source, ~~viewing~~ from ~~an~~ the aspect of the plasma and a wafer, since the side wall area is narrow, the deposition and the gas discharge ~~in~~ at the side wall have almost no ~~do not almost give the~~ influence ~~to~~ on the etching characteristic~~,~~; however, in the

narrow electrode type plasma apparatus in which ~~the~~ a low pressurization is used ~~devised~~, it is necessary to take a new countermeasure.

Further, to accomodate ~~correspond to~~ a large diameter ~~sizing of the~~ wafer, it is necessary to make the ~~uniform a~~ gas pressure distribution across the ~~in a~~ wafer face and the ~~a~~ reaction product distribution uniform; ~~and~~, for this purpose, it is necessary to provide a ~~form~~ wide ~~the~~ electrode interval, and ~~an~~ importance ~~of~~ so the area ratio of the side wall becomes ~~high~~ more and more important.

The influence of the affects of the reaction products ~~react product~~ which adhere ~~is adhered~~ to the side wall on ~~to~~ the etching characteristic is discussed ~~shown in~~ above, however, when the etching is continued ~~extending~~ over ~~during~~ a long period of time, a change of the influence ~~degree~~ becomes a problem.

For example, by repeatedly carrying out ~~repeatedly the~~ etching operations, the temperature of the side wall will rise ~~is risen~~ gradually. When the temperature of the side wall has ~~is~~ risen sufficiently, the characteristic of the adhesion and adsorption of the reaction products on ~~reaction product to~~ the side wall is changed, and, as a result, the etching characteristic fluctuates ~~is fluctuated~~.

Further, in a case where the amount of the deposition film on ~~to~~ the side wall accompanying ~~with~~ the etching is increased gradually, in accordance with the dependence on ~~to~~ the amount of the deposition film, it is possible to change the desorption and adsorption characteristic of the reaction products ~~product~~ at the side wall surface.

A phenomenon in which the etching characteristic ~~receives the influences according to the~~ is influenced by the time lapse change stated ~~in~~ above is known ~~in~~ particularly in the case of ~~the~~ oxide film etching. As a result, the temperature ~~adjustment~~ change of the side wall in the oxide film etching apparatus ~~is~~ represents an important problem.

In particular ~~particularly~~, in ~~the~~ a high electron temperature and high density plasma source, it is ~~compelled~~ necessary to establish ~~the~~ a high side wall temperature ~~high~~. In the case of a ~~above stated~~ high side wall temperature, even the side wall temperature ~~is fluctuated~~ fluctuate a little, and so the adsorption and desorption characteristic of the deposition film is changed largely. ~~With~~ For these reasons, it is necessary to restrain the side wall temperature fluctuation ~~in~~ to a small range, and ~~the~~ a high accuracy temperature adjustment, such as 200 °C ± 2 °C ~~is~~ needs to be carried out.

As stated ~~in~~ above, in any of the plasma sources, to satisfy the requirement ~~of the~~ for oxide film etching, namely ~~the~~ for obtaining ~~the~~ a high etching speed ~~by~~ , while attaining ~~the~~ a high selection ratio, ~~the~~ low micro loading, and the passing -through of ~~the~~ a deep hole, ~~it remains the problem~~ there still remain problems to be solved.

* The important problem in ~~the~~ an oxide film etching apparatus ~~is that~~ involves the dissociation of the gas ~~molecule~~ molecules ~~according to~~ as the plasma is being formed ~~as a~~ under the most suitable ~~condition in~~ conditions for the etching of the oxide film. To

address problem
correspond to this, it has proposed a new plasma
producing a
generation source having a high density plasma under low
has been proposed
electron temperature.

For example, as described in Japanese application
discloses a
patent laid-open publication No. Hei 8-300039, there is
UHF type ECR apparatus having a plasma excitation
in the the
frequency of UHF band from 300 MHZ to 1 GHz. An electron
in
temperature of the plasma which is excited by the
in , for example,
frequency band having the above stated range is low, from
is at
0.25 eV to 1 eV, and the plasma dissociation of C_4F_8 has a
level for suitable to the oxide film etching. Further,
an
since it is ECR (Electron Cyclotron Resonance) system,
a
even under the low pressure, it is possible to generate
a
the high density plasma.

achieving
As stated in above, for the correspondence to the
patterning on a of
fine practicing and the wafer large diameter sizing, it
is necessary to make the electron temperature low and to
prevent an excessive
restrain the excess dissociation of the etching gas, and
further to make the plasma density high.

make
Further, it is necessary to uniform the plasma
density, the gas pressure and the reaction product
uniform;
distribution on the wafer, and, as a result, it is
the
necessary to provide an apparatus in which an oxide film
etching characteristic is not changed extending over
of operation
during a long period.

Summary of the Invention:

~~An~~ It is an object of the present invention to provide a plasma processing apparatus and a plasma processing method, wherein, using a UHF type ECR plasma etching apparatus ~~enable for~~ to generate a high density plasma under a low electron temperature necessary for ~~an~~ oxide film etching etc., a fluctuation of ~~an~~ the etching characteristic can be restrained ~~small extending over~~ during a long period of operation.

Another object of the present invention is to provide a plasma processing apparatus and a plasma processing method, wherein, using a UHF type ECR plasma etching apparatus ~~enable for~~ to generate a high density plasma under a low electron temperature necessary for ~~an~~ oxide film etching etc., a premature stopping ~~stop~~ of ~~an~~ the etching ~~is not generated~~ does not occur, and in which ~~also~~ a stable operation or a stable processing ~~work~~ can be carried out.

The characteristic feature according to the present invention ~~is that~~ resides in a plasma processing apparatus ~~or~~ and in a plasma processing method using a vacuum processing chamber, a sample table for mounting a sample which is processed in said vacuum processing chamber, and a plasma generation means, ~~the plasma processing apparatus,~~ wherein, when ~~a~~ plasma processing is carried out by generating a plasma ~~according to an~~ by introduction of a gas into the processing chamber which contains at least carbon and fluorine, and by which ~~generating~~ a gas species is generated which contains carbon and

fluorine according to a plasma dissociation, said plasma generation means is being a plasma generation means in which a the degree of said plasma dissociation is in a middle range degree and said gas species containing the carbon and the fluorine is generated fully in the plasma, and wherein the a temperature of a region which forms a side wall of said vacuum processing chamber is controlled to have a range of 10 °C to 120 °C.

In a UHF type ECR plasma etching apparatus has having a UHF band microwave radiation antenna disposed at an opposite a position opposite to the a wafer, and an etching gas is supplied from a gas supply portion provided on an antenna portion an etching gas is supplied. The UHF band microwave is radiated directly to a the plasma from the antenna and is radiated in the plasma through a dielectric body which is provided at a periphery of the antenna.

In an electrode for mounting the wafer (a wafer mount electrode or a lower electrode), an etching position and a wafer delivery position are positioned located at separate locations, positions and an electrode raising ascent and descent lowering function is provided. A distance (it is called as an "electrode interval between distance") between the wafer mount electrode wafer and the antenna or the gas supply plate is established from as 50 mm to 100 mm taking into the consideration about such a re-association of a the reaction products product.

According to the plasma processing apparatus, a side wall temperature at a periphery of the electrode is

temperature adjusted ~~with~~ within a range of 10 °C to 120 °C, preferably a range of 30 °C to 50 °C. ~~The~~ As the side wall temperature ~~is fluctuated~~ fluctuates, a gas species is discharged from a deposition film ~~of~~ on the side wall, and this ~~gives~~ has an influence ~~of an~~ on the etching characteristic.

In accordance with the present invention, to restrain the above-stated influence, ~~a~~ the temperature control accuracy of the side wall is controlled ~~at~~ to ±5 °C. Since the side wall temperature is low, even when the temperature of the side wall ~~is fluctuated be at~~ fluctuates by 5 °C degree, ~~since~~ the fluctuation of a discharge gas amount which is discharged from the side wall will be small, so that the influence on the etching characteristic can be neglected.

Further, since the plasma source is a UHF type ECR system, ~~a~~ the plasma dissociation is in a middle range ~~degree~~ and a CFx species exists fully to a level necessary for the oxide film etching~~, since~~. Since the problem of a shortage of CFx species and an excess F, which ~~becomes the problems~~ is inherent in ~~the~~ a high density plasma source, can be solved, ~~and~~ to ~~heighten~~ increase the selection ratio, it is unnecessary to ~~heighten~~ increase the side wall temperature.

Herein, when the dissociation ~~exceeds over~~ is excessive, F or C becomes rich, and when the dissociation is ~~short~~ insufficient, there is a shortage of F, CF_2, CF_3, etc ~~become the shortage~~, accordingly, it is desirable to have ~~the~~ a plasma dissociation ~~with the~~ fall in middle ~~degree~~ range. Further, since the side wall temperature is controlled ~~the~~ to a low temperature, ~~even the~~ with a side wall temperature

control accuracy of is ±5 °C, the fluctuation of the etching characteristic can be restrained for at a long period of operation.

Brief Description of Drawings:

Fig. 1 is a schematic sectional diagram view showing an etching apparatus of a plasma processing system representing apparatus and a plasma processing method of one embodiment according to the present invention;

Fig. 2 is a graph view showing a size relationship of various kinds of plasma sources of a plasma processing apparatus and a plasma processing method of one embodiment according to the present invention;

Fig. 3 is a graph view showing a characteristic of a gas discharge from a deposition film of a plasma source sources of a plasma processing apparatus and a plasma processing method of one embodiment according to the present invention;

Fig. 4 is a graph view showing the an influence of a side wall temperature which gives an influence to on a time lapse change of a plasma source sources of a plasma processing apparatus and a plasma processing method of one embodiment according to the present invention;

Fig. 5 is a graph view showing an etching speed change in a case where a temperature adjustment of a side wall is not performed according to the prior art; and

Fig. 6 is a graph view showing an etching speed change in a case where a temperature adjustment of a side wall is

performed according to the present invention.

Description of an Embodiment of the Invention:

Hereinafter, a plasma processing apparatus and a plasma processing method of representing one embodiment according to the present invention will be explained.

Fig. 1 is an example of a UHF type ECR plasma etching apparatus. At a peripheral portion of an etching chamber 1 (a vacuum processing chamber), which is operated as a vacuum vessel, a coil 2 is installed, and this coil 2 generates an electron cyclotron resonance (ECR) use field. An etching use gas is supplied from a gas supply pipe 3 and is introduced to from via a gas supply plate 4 to the etching chamber 1. The gas supply plate 4 is comprised of a plate made of a silicon form or a glass form carbon in which about 100 number fine holes having a diameter of from 0.4 mm to 0.5 mm degree are provided.

At an upper portion of the gas supply plate 4, a disc form -shaped antenna 5 is provided, and this antenna 5 radiates a microwave energy in the having UHF band. The microwave energy is supplied to the antenna 5 is supplied from a power supply 6 through an induction shaft 7. When the microwave energy is radiated from a periphery of the antenna 5, an oscillating electric field in a of an upper space above of the antenna 5 is introduced into the etching chamber 1 through a dielectric body 8. Further, between the antenna 5 and an electrode 9, a volume combination

electric field is generated and this electric field becomes an effective plasma generation source. The frequency of the microwave is set to have a range of from 300 MHZ to 1 GHz and has a band area in which an electron temperature of the plasma has a low temperature of from 0.25 eV to 1 eV.

In this embodiment according to the present invention, the frequency band of a vicinity of 450 MHZ can be employed. Further, as the dielectric body 8, a quartz or an alumina can be employed. Further a heat resistant polymer having a small dielectric loss, such as a polyimide etc., can be employed.

The electrode for mounting a wafer (the wafer mount electrode or a sample table) 9 is provided on a lower portion of the gas supply plate 4 and a wafer 10 being a sample is supported through an electrostatic adsorption. To draw into the ions in the plasma to the wafer 10, a high frequency bias is applied to the wafer mount electrode 9 from a high frequency power supply 11.

Further, the temperature control of an inner wall of the etching chamber 1 being the vacuum processing chamber, which is an essential feature according to the present invention, is carried out at a temperature adjustment side wall 12 of the etching chamber 1. To the temperature adjustment side wall 12, not shown in figure, a coolant medium which has temperature controlled is introduced and the temperature adjustment

side wall 12 is maintained at a constant temperature. In this embodiment according to the present invention, the constant temperature in the temperature adjustment side wall 12 is set to have 30 °C.

The etching gas and the reaction products product are deposited on in the inner wall of the etching chamber 1 and also they are also deposited at the periphery and in a downstream area of the wafer mount electrode 9, so that a and the deposition film is generated which is the become the generation origin of the foreign matter in the etching chamber 1 matters.

Accordingly, it is necessary to clean periodically remove the deposition film, however, it is not always easy to remove a the strongly adhered deposition film. Herein, in this embodiment according to the present invention, the cleaning of the deposition film is carried out again using an exclusive cleaning apparatus.

The time used for establishing a vacuum state by transfer to a vacuum evacuation of the etching chamber 1, which has been opened to the air for cleaning, is important from an aspect of the a shortage of a non-operation time of the apparatus and further from an aspect of an improvement of the a productivity of the apparatus.

Accordingly, it is desirable to prevent that the deposition film from adhering on is tried to not adhere a portion where a the component exchange-over is not carried out easily, and to try to provide that the component to which the deposition film has adhered as a component which can be easily replaced by is tried to exchange over another clean prepared cleaning component. In this way As a result, the air opening time for cleaning in the etching chamber 1 can be shortened, and a reduction shortage of the

cleaning and vacuum evacuation time after that can be achieved improved.

In this embodiment according to the present invention, not to adhere to prevent the deposition film from adhering to the downstream region of the etching chamber 1, an a deposition film use cover 13 is provided on in the downstream region of the temperature adjustment side wall 12 of the etching chamber 1.

To the cover 13, a vacuum evacuation use and a wafer delivery use opening portion is provided. Since the deposition film are recovered by can be removed with this cover 13, the adhesion of the deposition film in the downstream region of the temperature adjustment side wall 12 can be reduced.

A vacuum chamber 15 is connected directly to the etching chamber 1, and a turbo molecular pump 14 having an evacuation speed of from 2000 L/s to 3000 L/s is installed in the vacuum chamber 15. Further, although not shown in the figure, to an opening portion of the turbo molecular pump 14, a vacuum evacuation speed adjustment use conductance valve 16 is installed, and this evacuation speed adjustment use conductance valve 16 is used for separating the turbo molecular pump 14 during the air chamber open time, or the evacuation speed adjustment use conductance valve 16 is used for not opening the chamber to the air.

Next, an example of an oxide film etching using the plasma processing apparatus of this embodiment according to the present invention will be explained.

To the etching chamber 1 which is ~~vacuum~~ evacuated ~~at~~ to a high vacuum condition, although not shown in the figure, the wafer 10 is carried in from a transfer chamber by a transfer arm, and the wafer 10 is delivered ~~on~~ onto the wafer mount electrode 9.

The transfer arm is ~~retarded~~ then retracted, and, after a valve arranged between the etching chamber 1 and a transfer chamber has been closed, the wafer mount electrode 9 is raised to ~~ascended and stopped~~ a position where the etching is to be carried out. In the case of this embodiment according to the present invention, ~~a~~ the distance between the wafer 10 and the gas introduction plate 4 (an electrode interval ~~between distance~~) is set to from 50 mm to 100 mm.

As the etching gas, a mixture gas comprised of Ar, ~~and~~ C_4F_8, and O_2 is used, and the respective flow amounts are 500 sccm, 10 sccm and 5 sccm ~~are introduced~~. The pressure of the etching gas is 2 Pa. ~~An~~ The output of the UHF microwave power supply 6 is 1 kW, and ~~an~~ the output of a bias power supply 11 to the wafer 10 is 600 W.

~~The~~ A current is applied to the coil 2 and a resonance magnetic field having 0.016 T of UHF ~~microwave having~~ energy at 450 MHZ is generated between the gas supply plate 4 and the wafer mount electrode 9 (namely the wafer 10). Next, the microwave power supply 6 is operated. ~~According~~ Due to the electron cyclotron resonance phenomenon, a strong plasma is generated in the ECR area having ~~the~~ a resonance magnetic field strength of 0.016 T.

To improve the uniformity of the etching characteristic, it is necessary to uniform an incident ion density on a surface of the wafer 10 and when ECR is positioned as stated in above and a shape of ECR area is formed at a raised shape toward a side of the wafer 10, as a result the uniformity of the ion current density can be attained.

After a spark of the plasm, not shown in figure, from a direct current power supply which is connected directly in parallel with the high frequency power supply 11, a high voltage is applied to the wafer mount electrode 9 and then the wafer 10 is electrostatic adsorbed to the wafer mount electrode 9.

At a rear face of the electrostatic adsorbed wafer 10, helium (He) gas is introduced, and the temperature adjustment of the wafer 10 is carried out between a wafer mount face of the wafer mount electrode 9 which has temperature controlled according to the coolant medium and the wafer 10 through the helium (He) gas.

Next, the high frequency power supply 11 is tried to be operated, the high frequency bias is applied to the wafer mount electrode 9. Accordingly, to the wafer 10 the ion is incident vertically from the plasm. In the oxide film etching, it is necessary to carry out the high energy ion incident.

In this embodiment according to the present invention, a high frequency bias voltage Vpp (the voltage

between the maximum peak and the minimum peak) ~~is made~~ has a value of from 1000 V to 2000 V. In response to ~~accordance with~~ the impact of ~~due to the~~ high energy ions with the wafer surface ~~ion~~, the temperature of the wafer 10 rises ~~is arisen~~.

In ~~the~~ oxide film etching, since the selection ratio is ~~become~~ high at ~~in the~~ higher temperature values, the etching characteristic has a superior characteristic, and so the wafer temperature is adjusted to a value of ~~having~~ several 10 °C.

However, since it is necessary to carry out the processing with ~~incident of the~~ high energy ions ~~ion~~, the ~~a~~ heat input amount to the wafer 10 is large, and so the coolant medium temperature of the wafer mount electrode 9 is set in the ~~to a~~ vicinity of ~~-~~ −20 °C.

At this ~~the same~~ time, when the bias voltage is applied to the wafer 10, the etching is started, and the ~~. The~~ etching is finished within ~~under~~ a predetermined etching time. Or, though not shown in the figure, by monitoring the ~~a~~ plasma luminescence strength change of the reaction products ~~product~~ and further judging the ~~a~~ finish point of the etching, an etching finish time can be determined, ~~is requested~~ and, after a suitable over etching has been ~~is~~ performed, then the etching is finished.

The ~~finish of the~~ etching is completed at a time when the application of the high frequency bias voltage is stopped. Simultaneously with this, the supply of the etching gas is stopped.

However, it is necessary to provide a process in which the electrostatically held ~~adsorbed~~ wafer 10 is released ~~adsorbed~~

from the wafer mount electrode 9, and as, for this purpose, an electric adsorption gas, such as an Ar etc., is supplied. By stopping the supply of the electrostatic adsorption voltage, and after, then connecting the an electric supply line is connected to an earth ground, while maintaining the discharge of the microwave energy, an electric adsorption time having of 10 seconds degree is allocated prepared. Accordingly, the electric charges on the wafer 10 are adsorbed by the earth ground through the plasma, and, as a result, the wafer 10 can be removed easily.

When the electric adsorption process is ended finished, the supply of the electric adsorption gas is stopped, and also the supply of the microwave energy is stopped. Further, the current supply to the coil 2 is stopped. Further, a height of the wafer mount electrode 9 is lowered descended, until the surface thereof reaches to the wafer delivery position.

After that, for some time, the etching chamber 1 is vacuum evacuated until the high vacuum is achieved. At a time point when of the high vacuum state has been reached evacuation is completed, the valve between the etching chamber 1 and the transfer chamber is opened and, the transfer arm is inserted therein, and then the waver 10 is delivered and is carried out. In a case of there is to be an existence of a next etching process, a new wafer is carried in and the etching is performed again according to the above-stated procedures.

In the above description, the representative flow of the etching process was explained.

The electron temperature of the UHF band microwave ECR

plasma is in a range of from 0.25 eV to 1 eV and the dissociation of C_4F_8 being, which is the etching gas, is, does not progress very much progressed. The dissociation of C_4F_8 is a complicated process one, however in which the gas species which contributes to the etching is first dissociated from CF_3 to CF_2, in next then CF is generated, and finally F is generated. As a result, the more higher the electron temperature is high, the more the plasma becomes rich in F one having F-rich plasma.

As stated in the Background of the Invention prior art item, to ensure the proper selection ratio in the oxide film etching, in the deposition of a film on the foundation silicon the deposition film are adhered and it is necessary to restrain the etching according to the high energy ion energy incident. Namely, since the high energy ions are incident on the wafer, when there are is no deposition film, there is a possibility in which that the etching is will progress progressed according to a physical sputter.

As a result, for the etching to progress the etching, it is necessary to supply the high energy ions to the bottom of a hole bottom, however to ensure the required selection ratio, it is necessary to supply the radicals which form the a deposition film. It is said that the radicals for forming the deposition film are CF_3 and CF_2.

On the other hand In reversely, F radicals form SiF_4 etc. and the foundation silicon is caused made to be etched. As a result, to perform the high selection ratio etching, it is necessary to make CF_2/F (CF_2-F ratio) large. In the case of UHF

band microwave ECR plasma, ~~sine~~ since the electron temperature is low, the generation amount of F is small, ~~the~~ and a plasma having ~~the~~ a plentiful amount of CF_3, CF_2 and CF is formed.

Accordingly, as shown in the case of ~~the~~ a high electron temperature and ~~the~~ a high density plasma, to supply CF_2 and CF_3, which become insufficient ~~by~~ due to the excessive progress of the ~~plasma~~ dissociation of the plasma, it is unnecessary to heat the inner wall of the etching chamber 1 to more than 200 °C.

As the necessary points for achieving a ~~the~~ fine ~~practicing~~ processing correspondence etching, the following points are stated, namely (1) under ~~the~~ a low electron temperature, the plasma dissociation is restrained suitably and ~~the~~ a plasma having ~~the~~ a large CF_2/CF (CF_2-CF ratio) is generated~~,~~; (2) the discrepancy between a ~~from~~ 90° angle ~~of~~ and the ion incident angle is restrained to a small value and a tapering formation of the etching shape~~,~~; and (3) even when the etching is repeated many times, the fluctuation of the etching characteristic is small~~, etc~~.

In addition to the above, an item relating to the etching characteristics is an important development problem, however, in the present specification, such an item is not mentioned.

The above-stated ~~(1)~~ (1) item for the necessary points for the fine ~~practicing~~ processing correspondence etching is solved by the use of the UHF band microwave plasma etching apparatus according to the present invention.

As to the above-stated ~~(2)~~ (2) item for the necessary

points for the fine practicing correspondence etching, a main cause is that the orbit of the ions is ~~displaces~~ displaced according ~~to~~ with the collision of the ions and ~~the~~ a gas ~~molecular~~ molecule in the vapor phase, and so it is effective to lower the pressure to lessen the ~~collision of the molecular~~ occurrence of such collisions.

Since the UHF band microwave plasma etching apparatus according to the present invention ~~is used the~~ uses electron cyclotron resonance, it is possible to generate the plasma under ~~the~~ a low pressure.

As to the above-stated ~~(3)~~ (3) item, for the necessary points for the fine ~~practicing~~ processing correspondence etching, it is necessary to ~~not fluctuate~~ prevent fluctuation of the etching characteristic, even when number of the etching ~~time numbers~~ operations which are repeated ~~at~~ is in the order of several hundred ~~order~~; namely, it is necessary to restrain the time lapse change.

A main cause of the time lapse change is the time fluctuation of the ~~gas~~ kinds of gas, which are discharged from the deposition film which ~~adhere~~ adheres to the inner wall (the side wall, the ceiling, etc) and ~~the~~ other components of the etching chamber 1. ~~In concretely~~ More specifically, the temperature fluctuation of the members to be subjected to the processing, such as the side wall ~~occupies the~~ represents a large cause of the problem.

As a countermeasure ~~of~~ against the restraint of the time lapse change, basically the apparatus is formed so as to ~~not fluctuate~~ prevent fluctuation the desorption and adsorption phenomenon of the deposition film ~~of~~ on the wall face ~~according to the~~ using temperature control~~,~~; however, in ~~accordance with the~~ various

plasma generation systems, the wall face area used ~~necessary~~ to form ~~as~~ the apparatus differs.

The relationship between the etching chamber height and the side face area is shown in Fig. 2. In the narrow electrode type plasma ~~type~~ apparatus, the height of the etching chamber is low, and also the area of the side wall face is narrow. On the other hand, in the high density plasma ~~type~~ apparatus, the height of the etching chamber is high, and also the area of the side wall face is wide.

In the UHF type ECR apparatus according to the present invention, the height of the etching chamber (the electrode interval ~~between distance~~) and the area of the side wall are positioned intermediately relative to the other types of apparatus, and the apparatus occupies a ~~the~~ region which is suitable for ~~the~~ oxide film etching.

Namely, according to the present invention, the height of the etching chamber (the electrode ~~between~~ interval ~~distance~~) and the area of the side wall has a middle value ~~having~~ in the 30 mm -100 mm range of the narrow electrode (about 30 mm) and the microwave ECR induction type (more than 100 mm).

The height of the etching chamber, namely the electrode interval ~~between distance~~, is a distance of from 50 mm to 100 mm, and the reaction products ~~product~~ generated by the etching are ~~is~~ re-dissociated and ~~is~~ re-incident on ~~to~~ the wafer 10.

For ~~With~~ the above stated reasons, the etching characteristic of the oxide film is influenced ~~receives an influence~~,

however, this is caused by making the most suitable performance to the influence degree, such as the re-dissociation and the incidence ~~incident~~ of the reaction ~~product~~ product etc. with the etching characteristic of the oxide film.

Namely, in this embodiment according to the present invention, the electrode interval ~~between distance~~ is ~~formed~~ set ~~according~~ to a predetermined distance which is determined by a relative relationship of ~~a~~ the mean free ion path in the ~~stroke at a~~ vicinity ~~of the~~ at a pressure of 2 Pa.

Since the electrode interval ~~between distance~~ is ~~formed by~~ set to the above stated distance, the pressure distribution on the face of the wafer 10 can be made uniform ~~uniformed~~. In a case where the wafer diameter is large, such as ~~formed largely~~ from 200 mm to 300 mm, the difference in pressure between the center and the periphery of the wafer 10 can be small ~~fully~~.

Further, since the conductance, which depends on the electrode interval, ~~between distance~~ is ~~formed~~ large, a high speed of evacuation of the chamber to a ~~the~~ high vacuum ~~evacuation speed~~ can be attained ~~obtained large fully~~, and, as a result, the ~~stay~~ time during which ~~of~~ the etching gas and the reaction products remain in the chamber ~~product~~ can be shortened easily.

In a case where the area of the side wall is further widened ~~wide~~, there is a possibility ~~in which~~ that the adhesion amount of the deposition film becomes large, with ~~and then~~ the result that the ~~influence~~ degree of influence on ~~to~~ the etching characteristic becomes large. In an ~~the~~ apparatus for maintaining a ~~the~~ high density plasma, according to the requirements ~~request~~ of the plasma generation method, it is necessary to form the height of the etching

chamber to a range from 100 mm to 200 mm.

Accordingly, the rate in which the area of the side wall occupies largely in a whole area of the etching chamber is high and the influence during the fluctuation of the etching gas and the deposition of the reaction product in the side wall is large.

As the methods for restraining this influence, there are methods in which the temperature fluctuation of the side wall is made to lessen or the side wall is heated under the high temperature to not adhere the deposition film.

Further, as stated in the former portion, in the apparatus using the high density plasma source, since the electron temperature is high, the plasma having F-rich plasma is generated, to ensure the selection ratio it is necessary to reduce the gas species which adheres to the side wall or it is necessary to promote the gas discharge from the deposition film, as a result it is necessary to make the side wall at the high temperature.

With the above stated reasons, in the high electron temperature and the high density plasma etching apparatus, the side wall is heated at 200 °C degree and the temperature fluctuation is temperature adjusted at a range of ± 2 °C.

However, it is difficult technically to heat the side wall at the high temperature more than 200 °C and also it is difficult technically to restrain with the

high accuracy, the temperature fluctuation to as little ~~such~~ as ± 2 °C. Further, such a technique ~~and further it~~ invites ~~the~~ a complicated structure for ~~in~~ the apparatus and a problem in ~~the~~ reliability, as well as an increase ~~and the rise~~ in cost. Further, the side wall comprises ~~has the same meaning to~~ the entire inner wall of the etching chamber, ~~the side wall~~ and includes the top plate and other portions which contact ~~to~~ the plasma.

~~Further, in~~ In a portion ~~is one~~ where the deposition film adheres, ~~when such a portion~~ but which is not contacted directly by the plasma, since this portion has a possibility for affecting the etching characteristic, ~~in compliance of the apparatus,~~ it is necessary to take such portion fully into ~~an~~ consideration ~~attention~~.

Further, in the apparatus according to the present invention, since the side wall is ~~has~~ from 50 mm to 100 mm ~~degree~~, ~~in~~ the downstream region thereof ~~it~~ can ~~admit~~ hardly comprise a ~~the~~ region where the deposition film is adhered.

As a result, ~~as the~~ for oxide film plasma etching ~~apparatus~~, it is desirable to provide ~~the~~ an apparatus in which ~~the~~ fluctuation of the etching characteristic is not generated, even when the temperature adjustment accuracy in the control of the side wall temperature is mitigated.

In the UHF type ECR plasma apparatus according to the present invention, it is unnecessary to ~~heighten~~ increase the side wall temperature to improve the selection ratio. There is ~~a merit in which~~ the advantage that the side wall temperature can be established ~~according to~~ from the view point of the restraint

of the time lapse change.

Fig. 3 shows the results in a case in which when the temperature of the deposition film was is changed 1 °C, and the gas discharge amounts from the deposition film were measured.

It is understood seen from these results that when the temperature of the deposition film is high, a large there appear much gas amount of gas which is discharged with a according to the temperature fluctuation of 1 °C. It is supposed that when the gas which corresponds to the flow amount of 0.01 sccm by the conversion calculation of the flow amount of the etching gas, there is a possibility that the etching characteristic is influenced, given the influence and the temperature adjustment range of the side wall temperature of at this time is shown in on the right side in Fig. 3.

In the a case of a wall temperature of 200 °C, when the side wall is not controlled at to ± 2 °C, the fluctuation of the gas discharge amount becomes less than 0.01 sccm. On the other hand, when the side wall temperature is controlled to less than 120 °C, even the side wall temperature changes the cause a small change in the gas discharge amount is small.

Namely, it is understood that even when the control accuracy of the side wall temperature is controlled with ± 5 °C and ± 10 °C, the gas discharge for giving the an influence to the etching characteristic does not occur.

In the etching apparatus according to the present invention, the side wall temperature is established at within a

range of from 10 °C to 120 °C. Preferably, it is controlled from the room temperature 20 °C to 50 °C.

With this temperature range, since the etching chamber is not heated ~~at the~~ to a high temperature, there ~~are~~ is the advantage ~~merits~~ that the ~~dimension~~ size of the apparatus is small, and the materials ~~of~~ used for the vacuum sealing and materials ~~the material~~ having ~~the~~ a different thermal expansion coefficient can be used freely, and the temperature control can be performed easily.

According to the present invention, ~~it employs the~~ system is provided in which ~~the~~ a coolant medium which is connected to the temperature adjustment means is introduced to the side wall. By the employment of ~~the above stated~~ such a system, the temperature control ~~performance~~ can be carried out to less than ± 10 °C.

Further, Fig. 3 shows the results in which the discharge amounts from the deposition film were measured ~~searched~~. When the side wall temperature ~~becomes the~~ reaches a high temperature ~~having~~ of more than 200 °C, since the adhesion amounts of the deposition film themselves become small, in ~~the~~ an apparatus having ~~the~~ a high temperature control in which ~~the~~ a deposition film does ~~are~~ not adhere ~~adhered~~, as shown in ~~an~~ the example ~~in~~ of Fig. 3, ~~the~~ substantial gas discharge amounts become small.

The stability of the gas discharge amounts and the magnitude ~~largeness~~ of the fluctuation amounts into which the consideration of the adhesion amounts is taken are shown

in Fig. 4.

In Fig. 4, the horizontal axis indicates the side wall temperature of the etching chamber, and the vertical horizontal axis indicates the relative largeness degree magnitude about of the deposition film amount, the influence degree of influence on to the time lapse change and the gas discharge amount.

The gas discharge amount from the deposition film increases abruptly for side wall temperatures which exceed from a vicinity which exceeds over 200 °C. On the other hand, the adhesion amount of the deposition film which adheres to the side wall (the deposition speed) reduces gradually in proportion to an increase in the proportional to the high temperature and decreases abruptly for temperatures in excess from the vicinity of 200 °C.

The reason for this is that why when the temperature exceeds over 200 °C and further when the temperature exceeds over more than 300 °C, the deposition film does is not adhere adhered to the side wall.

Accordingly, in the temperature range of the AREA region 1 in Fig. 4, since the side wall temperature is low, the influence for referring to the etching characteristic to the deposition film of the side wall is small. Further, in the AREA region 3 in Fig. 4, since the temperature is high, the gas discharge amount from the unit deposition film is large much, however the a deposition film will is hardly adhere adhered, and as a result, the gas discharge amount is small, and the influence on to the etching characteristic is small.

However, in the AREA region 2 in Fig. 4, which represents an is the intermediate temperature range between AREA 1 and AREA 3 the both, the

deposition film is comparatively large and the gas discharge amount is much, as a result the temperature fluctuation of the side wall is given the influence largely to the etching characteristic.

Taking into the consideration from the above-stated points, to restrain the time lapse change, the side wall temperature is set to the region 1 or the region 3. The temperature range of the region 1 is less than 120 °C and in the region 3 the temperature range is more than 200 °C and in the region 2 the temperature range is from 120 °C to 200 °C.

According to this embodiment according to the present invention, the side wall is established the temperature range of the region 1 in Fig. 4. Further, from the principle, the side wall temperature may be establish to the low temperature, however taking into consideration the temperature establishment is easily the temperature and the coolant medium is not presented to the drew condensation, the lower limitation temperature is set to 10 °C.

Fig. 5 shows that in UHF type ECR plasma etching apparatus of the embodiment according to the present invention, the etching speed fluctuation is shown in a case of using the mixture gas containing Ar and C_4F_8, the continuous etching is carried out.

In this time, since the temperature adjustment of the side wall is not carried out, the temperature

fluctuation is risen accompanying rises with the discharge time of the plasma and is risen to 60 °C degree from the room temperature. The temperature fluctuation is ± 20 °C degree. The etching speed of the silicon nitride at the etching starting time is becomes high, as a result of it can be admitted the fluctuation of the etching characteristic.

On the other hand, Fig. 6 shows the etching characteristic in a case where the temperature adjustment of the side wall is carried out.

After the etching chamber is opened to the air and evacuation of the chamber is carried out the vacuum evacuation, but without the performance of the covering about the inner portion of the etching chamber by the deposition film and also the process for presenting the regular state, regardless immediately after the etching is started, the etching characteristic is stable from the starting time of the etching, and the fluctuation after that is not hardly in evidence admitted. Further, the side wall temperature fluctuation at this time is within ± 5 °C.

As understood from the above-stated results, in a UHF type ECR plasma etching apparatus, according to the performance of by performing a the temperature adjustment of the side wall, an the extremely stable etching characteristic can be obtained.

Further, in this embodiment according to the present invention, it is assumed explained on the assumption that a UHF type ECR plasma etching apparatus is used, however, when

the plasma source is suited for the etching of the oxide film, it is not limited to UHF type ECR plasma etching apparatus.

Namely, when the electron temperature in the plasma is the low electron temperature having less than 1 eV and further the high density plasma is used, for example, it can employ the apparatus using the pulse plasma source in which the application of the microwave is carried out intermittedly.

Further, it can employ the apparatus using the plasma source in which the induction type plasma except for the microwave is pulse driven. When the side wall of the etching chamber of these plasma sources is established at a range of 10 °C to 120 °C, it is possible to obtain the superior oxide film etching characteristic and further it is possible to exhibit the stable characteristic during the long period.

Further, the temperature adjustment of the side wall is exemplified using the coolant medium, however it is not limited the coolant medium, it can employ any one of the use of the compulsory cooling using the water cooling and the vapor cooling, the heater, the lamp heating using the infrared ray.

To summarize, the temperature range must be formed with the range of 10 °C to 120 °C. With the above stated temperature range, even the temperature adjustment range of the side wall is ± 5 °C degree, the fully stable

etching characteristic can be obtained.

According to the etching characteristic, even when the temperature adjustment range of the side wall is ± 10 °C degree, the a stable etching characteristic can be obtained, and further the temperature adjustment can be carried out extremely easily.

According to the present invention, since the a superior oxide film etching characteristic can be obtained and further the a stable characteristic can be obtained during a the long period of operation, the following advantages merits can be expected.

Namely, the yield can be improved and the throughput can be improved. Further, since the temperature adjustment is established in a to at the low temperature range of from 10 °C to 120 °C, the inconvenience in which the size of the etching chamber is made large due to by the thermal expansion can be avoided.

For example, the line expansion coefficient of the aluminum alloy which is largely used in the etching chamber is 24 x $10^{-6}K^{-1}$; on the other hand, for in the alumina and quartz, the respective line expansion coefficients are is 6 x $10^{-6}K^{-1}$ and 0.41 x $10^{-6}K^{-1}$.

Since the line expansion coefficients differ so much, when the etching chamber is heated to produce according to the plasma discharge or the etching chamber is temperature controlled compulsively at a the high temperature, the differences in the dimension sizes between the materials

become large ~~and then~~, making it ~~is~~ necessary to ~~devise~~ design the chamber to avoid structurally ~~the avoidance of the~~ thermal expansion.

Further, the ~~size~~ change in size of the vacuum sealing portion exerts an ~~gives the~~ influence on ~~to~~ the sealing characteristic, and ~~further~~ the heat resistant performance of the elastomer ~~being~~ which forms the seal material also becomes a problem.

When the temperature ~~becomes high to the~~ reaches a level of more than 150 °C, the possibility ~~in which~~ that the life of the seal material will be ~~presents~~ short becomes high.

As stated ~~in~~ above, ~~there cause the~~ various problems are caused ~~in which the avoidance appears~~ due to ~~the~~ high temperature, and the addition of heat resistant performance ~~is added~~ causes structurally, ~~and~~ the cost of the apparatus to increase ~~increases~~.